Assessing Regional Sustainability with the EPSILON Project

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SMIA – Geneva September 2005

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The EPSILON project (Environmental Policy via Sustainability Indicators On a European-wide level --2002-2005) is delivering a GIS integrated computerized model for benchmarking European regions through an aggregation of indicators represented on sustainability maps. Assessing sustainability within the EPSILON project has been addressed over four spheres/pillars: the environmental, the economic, the social and the institutional dimension as defined by the UN Commission on Sustainable Development. A coherent objective based structure has been defined relying strongly on the analytical DPSIR framework (Driving-Forces, Pressures, State, Impact and Response model from the European Environmental Agency). Such structure has been defined through a relevant definition of Indicators, sub-themes, themes and pillars for which maps at national level over 15 European countries are provided. Regional maps are also provided at regional levels (NUTS II and NUTS III levels). These results should not be considered as absolute figures but rather as an attempt of a relative sustainability assessment. Such regional sustainability assessment illustrates the interest to move down from a national assessment to a more local level by revealing higher data dispersion and detecting for example specific environmental issues, which would have been levelled otherwise at national scale.

An attempt to assess sustainability

The main foreseen application of the EPSILON model [1] is benchmarking between European regions. This will enable to identify main strengths and weaknesses of one region in comparison to others. It will also enable to assess regional evolution over time. A main interest would also be to provide a tool in policy decision making related to the improvement of regional sustainability.

Ideally, policy impact should be measured and predictions of the change of driving forces on several indicators should be possible. It is clear that EPSILON is only providing a contribution in that very demanding objective, but the effort to link the identified driving forces to a limited number of indicators is one important task in EPSILON and is the first step in building such a decision tool.

Building such model required for:

- The definition of what is sustainability and how to measure it,
- The elaboration of a conceptual and analytical structure for aggregation and establishing links between indicators,
- The selection of a core set of regional indicators, common to all regions, tracking all dimensions of interest to sustainability.

Assessing sustainability is a very delicate issue. No definite consensus exists yet at the conceptual level neither at the methodological level and the debate, initiated a few years ago in 1992 starting from the Brüntland definition is still going on. Defining sustainability is in itself a challenge and several definitions are to be found ranging from "weak" sustainability to "strong" sustainability [2] in the economic field, to resilience in the ecologic realm.

After an extensive study of the models available in the literature and previous attempts to construct operational tools, the framework developed in EPSILON has been derived from two major conceptual models:

1. The **DPSIR** model which differentiates levels of indicators (driving-forces, pressures, state, impact and response levels).
2. The "**four spheres**" model, from UN-CSD [3], which is a 4 dimensions view of sustainable development (social, economic, institutional and environmental).

The DPSIR approach initiated by EEA (European Environmental Agency) is providing a solid basis for helping setting a sound framework. It differentiates categories of indicators in order to explain the modification of the *state* of the environment resulting from the *pressure* put by human activities on the environment and the *impacts* of such changes. It also includes the individual or collective *response* to these impacts. Such approach is in fine accordance with our initial expectation for EPSILON to answer policy issues. Within EPSILON, sustainability is therefore addressed in various ways over the four dimensions/pillars: the environmental, the economic, the social and the institutional dimension. The social pillar is looking at the human-being' situation as well as the social welfare for all citizens. The economic pillar aims at reporting the financial prosperity of the region by assessing economic performance and efficiency. The institutional pillar proposes an assessment of the regional governance (how the whole society is acting and the resulting outputs). The environmental pillar reports about the State of the environment.

The first version of the EPSILON project aims at elaborating a first operational version of the measurement framework. Considerations of data availability are therefore of uttermost importance. First maps assessing regional environmental sustainability are now analysed following a short description of the environmental pillar structure.

The environmental pillar definition

The environmental pillar relates about the *state* of the environment within the DPSIR model. Four themes have been defined, three related to the environmental medias: Air, Soil and Water and one related to the state of ecosystems. The fourth dimension is however only assessed indirectly, through a proxy: Land, since the qualification of the Land, in terms of wilderness and naturalness state is directly linked to biodiversity [4]. The first three themes do provide a balance representation of the local quality of environment in terms of air, water and soil. Each Theme is then defined by several sub-themes which are defined in relation with EU priority policies for sustainable development [5]. In relation to the 4 themes and their corresponding sub-themes, indicators have been defined at the *state* level following as much as possible the European Environment assessment framework with coherent indicators selection [6]. The structure of these indicators and their 50 related data are fully described on Table 1. In order to reach an operational framework, indicators with poor data availability have not been integrated.

Table 1. Themes, sub-themes and indicators for the environmental pillar - Version 1.

Themes (4)	Sub-themes (16)	Indicators (25)	Data (50)	DPSIR
Air Index	Climate Change	Global Warming Potential	(6) CO2, CH4, N2O, HFCS, PFCs, SF6	P
	Air quality 1	Inorganic substances	(4) PM Total, NO3, NO2, SO2	S
		Organic substances	(1) Ozone	S
	Air quality 2	Heavy metals	(3) Lead, Cadmium, Mercury	S
		POPs and PAH	(5) PCB, BaP, BbF, HCB, g-HCH	S
	Noise	*To be defined in a second stage*		
Soil Index	Soil sealing	Build up area	(1) fraction of build area	S
	Soil degradation	Acidification	(1) fraction of land with acidification exceedance	S
		Salinisation	(1)electrical conductivity	S
	Soil toxicity	Heavy metals	(3) Lead, Cadmium, Mercury	S
		POPs and PAH	(5) PCB, BaP, BbF, HCB, g-HCH	S
	Soil loss	Water erosion	(1) fraction of land vulnerable to water erosion	S
Water Index	Water quantity	Water intensity	(1) ratio of water abstraction/Long term freshwater resources	S
		Ground water extraction	(1) ground water extraction	S
		Surface water extraction	(1) surface water extraction,	S
		Water stress	(1) fraction of land under water stress	S
	Surface water quality	River quality	(4) Nitrate, Ammonium, mercury, cadmium	S
		Lake quality	(2) Nitrate, phosphorus	S
	Groundwater quality	Nitrate	(1) Nitrate	S
		Hazardous substances	(2) atrazine, simazine	
	Ocean quality	Chlorophyll	(1) Chlorophyll	S
		Quality of bathing water	(1) Quality of bathing water	S
Land Index	Fragmentation	Area fragmentation by transport	(1) Ratio of area fragmentated by transport	S
	Natural land	Natural Land area	(1) Ratio of Natural Land over Intensive Agriculture and Artificial Areas	S
	Wilderness	Wilderness area	(1) Ratio of wilderness area over total area	S
	Wetlands	Wetlands area	(1) Ratio of Wetlands area per region	S

Aggregating indicators into an environmental composite index

The issue now is to convert and reduce these 50 indicators into limited meaningful indexes to ease the environmental EU regional benchmarking. Several proposals exist to reduce sets of indicators to a limited core set, ranging from explicit subjective selection (highly dependant on the stakeholders) to a systematic hierarchical scheme based on composite indicators strategies. Examples of indices related to the environment and its sustainability are numerous: The Pilot Environmental Performance Index (EPI) [7], The Environmental Sustainable Index (ESI) [8], The Well-being Index [9], the ecological footprint (WWF) [10] … They all provide global indicators in order to facilitate the countries ranking over the world following a wide range of composite scheme procedures. A very complete state-of-the-art report has been issued [11][1] on all possible methodological approaches (ranging from statistical techniques to public opinion via aggregating techniques) and recommendations for best-practice methodologies for composite index construction do exist [12], [13].

Building a composite index requires establishing a ranking among the indicators. Such ranking is a delicate task as indicators could address very different issues which are usually not related. Most attempts to derive a unique composite index from complex systems have clearly shown the difficulties of such exercise as it requires being able to give value to issues where they clearly depend on actors' preferences.

EPSILON solves this issue in three ways: First it will provide 4 separate indices, one for each sustainability dimension, avoiding grouping together conceptually very different types of indicators. Second, within each pillar, prior to any indicators weighting, model coherence is assured to provide a sound basis for the default aggregation scheme: equal weighting. Third an expert weighting based on scientific expertise is provided when possible such as the IPCC GHG factors [14].

A new scientific weighting scheme: impacts on human health

A new scientific weighting between indicators accounting for their impact on human health has been proposed within EPSILON model [15]. This aggregation scheme is valid for most of the environmental state indicators and is based on their assessment of their potential impact on human health expressed in DALYs (Disability Adjusted Life Years) using the model IMPACT2002+ [16] developed at EPFL. IMPACT2002 has been specifically developed for providing risk-based toxicological effect indicators in life cycle assessment (LCA) [17]. New weighting factors linking environmental concentrations (which are the *state* indicators for the environment) to human damages have been defined. Such approach allows comparing the environmental state indicators based on a same metric, i.e. their potential damage on human health. Starting from these concentrations (issued from EMEP database), a factor linking concentrations to the potential Impacts on human health has bee determined. The "Concentration to Damage Factors" (CDF) is expressed in DALYs/year/concentration/capita.

Regional maps for the air quality index 2

EPSILON composite indexes can be visualized through GIS maps over the 15 EU countries and report data collected from year 2000. Outputs are possible at several scales: NUTS0[2] represent the national scale, NUTSII and NUTSIII represent regional scales. Access is possible at all levels (indicator/sub-theme/theme) giving the user a wide choice of maps across the whole structure made of more than 100 indicators (50 for the Environmental pillar). EU benchmarking at NUTSIII level is now proposed with an illustration for the Air quality index 2 (Figure 2). This air quality index

[1] a complete list is also to be found on http://farmweb.jrc.cec.eu.int/ci/

[2] Nomenclature of Territorial Units for Statistics is a standard geocode for referencing the administrative division of countries for statistical purposes

illustration enables to understand the regional specificities in terms of environmental state. Starting from a large structure covering a wide spectrum of environmental issues (the environmental pillar is defined with about 50 environmental indicators), it is first possible to identify the global and specific issues to regional situations through composite indexes. Using a new weighting scheme based on human health impact, it is therefore possible to identify the most impacted regions by crossing current data concentrations of pollutants with their potential damage.

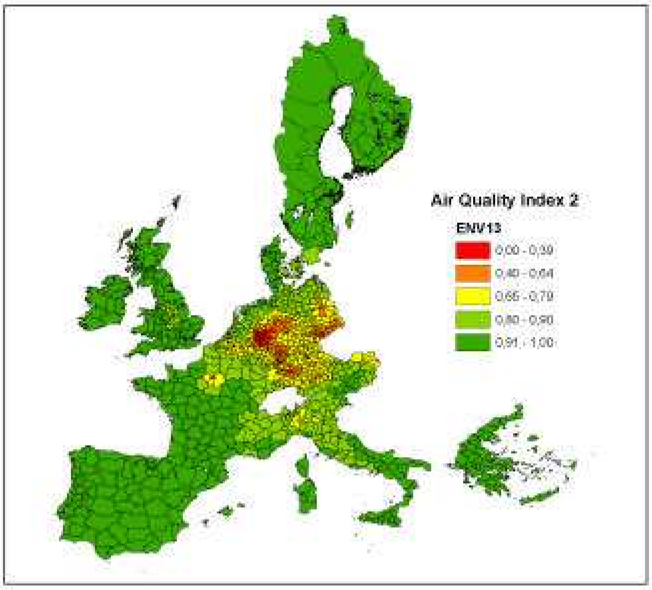

Figure 2: Air Quality Index 2 (normalised values)

Results on Figure 2 are expressed with normalised values ranging from 0 (red colour) to 1 (green colour). These values have been normalised using for the lower reference the minimal value of the data range and for the upper reference the maximal value of the data range. Such representation is providing a benchmarking across the 1000 NUTSIII regions for the Air quality index 2. It is a relative assessment and not an absolute assessment in relation with any EU concentration targets. One has to note that intervals have not been defined as equal on this figure but do correspond to the application of a space model in order to emphasize the particularities of the geo-referenced data [18].

The Air quality index 2 is made of 2 indicators: the Heavy Metals index (Figure 3) and the POPS index (Figure 6). The Heavy Metals index is itself composed of the Lead indicator (Figure 4), the Mercury indicator (Figure 5) and the Cadmium indicator on which specific DALY weightings have been applied to take into account their relative impact on human health. One can notice that Lead concentrations are in average 10 times higher than Mercury concentrations. However, Mercury has been identified as being 100 times more harmful on human health than Lead. The composite index scheme directly incorporates this knowledge through the relevant DALY weightings: the resulting Heavy Metals map on Figure 3 is much closer to the Mercury map (Figure 5) than to the Lead one (Figure 4).

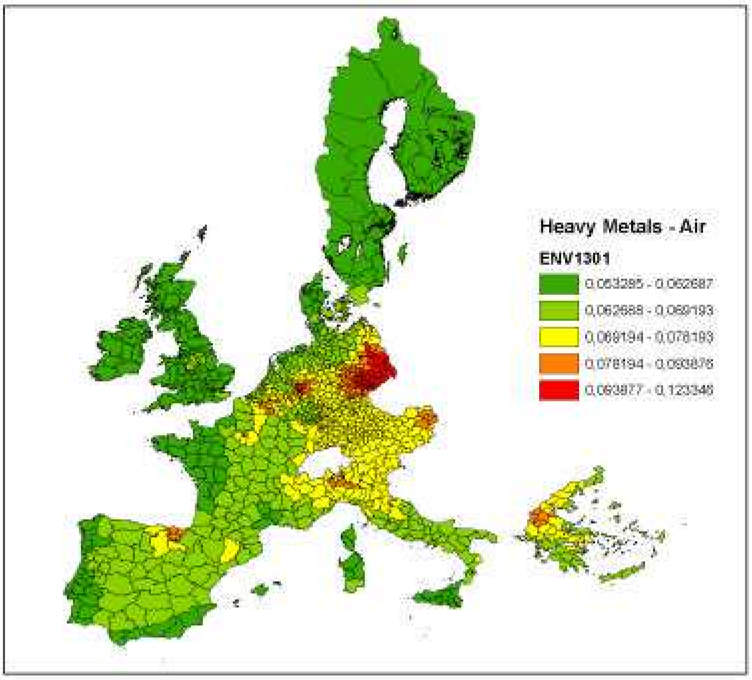

Figure 3: Heavy Metals Index (10^{-5} DALY/pers)

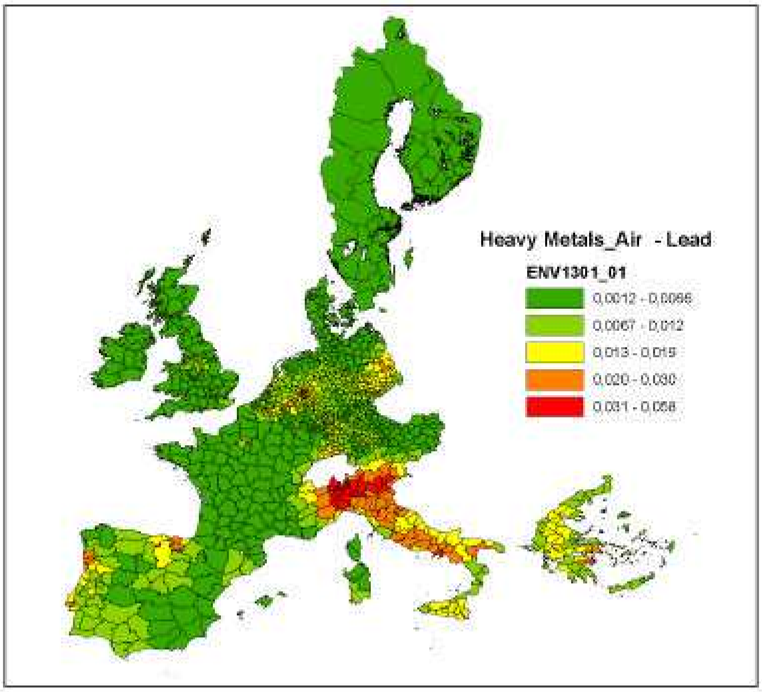

Figure 4: Air concentrations of lead (10^{-6}g/m3)

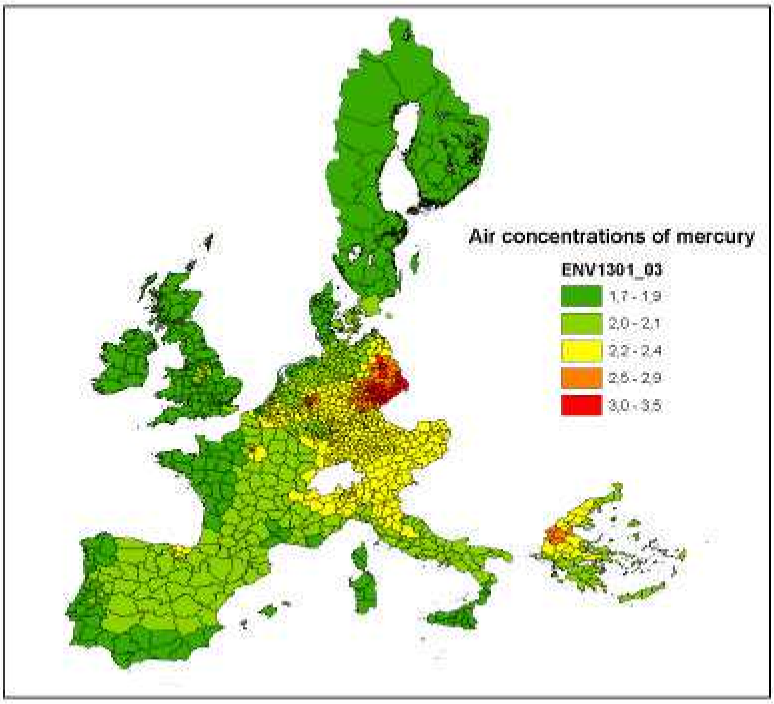

Figure 5: Air concentrations of mercury (10^{-9}g/m3)

The second indicator within the Air quality index 2 (Figure 2) is the POPs indicator (Figure 6). Impact assessments methods weight POPs more heavily than Heavy Metals index, which is of second order importance compared to the POPs indicator in terms of human health impact. The final map for the Air quality index 2 is therefore very close to the POPS one.

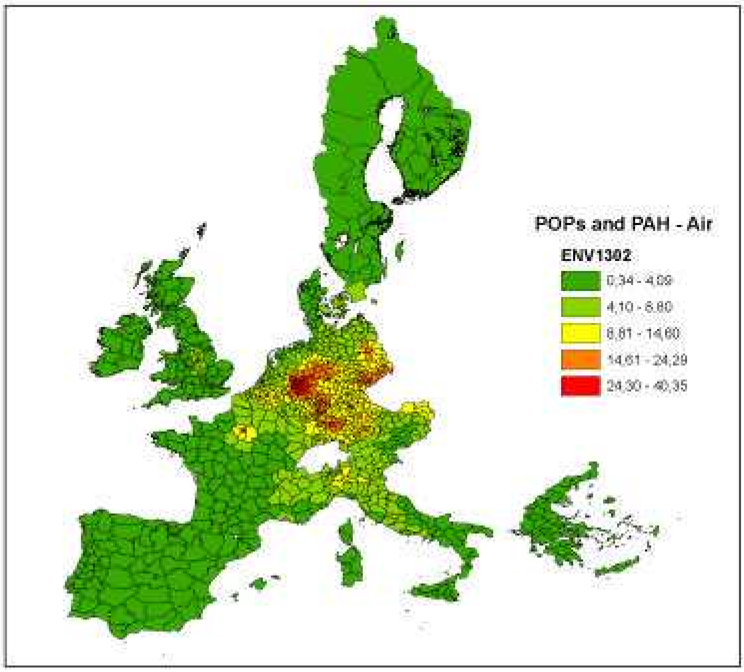

Figure 6: POPS Index (10^{-5} DALY/pers)

CONCLUSIONS

The aggregated results of the air quality index 2 raise the following comments:

- German regions are, overall, the most severely damaged as far as the air quality index 2 is concerned. This is due to the large impacts occurring from POPs and PAH concentrations and the relative lower impacts from the heavy metals. While regions from Northern Italy score comparatively particularly badly regarding Lead concentrations, their total damages are relatively low due to their low POPs and PAH concentrations. Weighting indicators through the relative assessment of human health impact shows its full relevance,
- Northern and Southern Italian regions do not follow the same pattern in terms of environmental state and a national assessment would have missed such regional discrepancies.
- These results have been derived from EMEP 2001 air data concentrations. Time series comparison is necessary to provide vital information on how regions are on the track of sustainability.
- The identification of regions with higher damages is however only the first step in the identification of adequate actions. By working at the *state* (concentration) level, no information is given on the sources of emissions and the responsible driving-forces. In addition, the smaller the region under study is, the larger the influence of other regions on the local environment is. Assessing regional sustainability certainly requires to explain these related influences between the regions.

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